THE EFFECT OF A NEW PITFALL TRAP DESIGN ON THE CAPTURE ABUNDANCE OF THREE ARTHROPOD TAXA

RICHARD BASHFORD and NITA RAMSDEN

Forestry Tasmania, GPO Box 207, Hobart, Tas 7001
(Email: dick.bashford@forestrytas.com.au)

Abstract

A guide-arm pitfall trap design, suitable for biodiversity studies in remote or difficult terrain forest sites, was tested against a standard pitfall trap to determine effective capture of beetles, ants and spiders of different size classes. Paired sets of traps were established at unshaded and shaded sites within a *Pinus radiata* plantation and a *Eucalyptus nitens* plantation in Tasmania and run for 6 months. Overall results show that the guide-arm trap design had a significant effect on the capture abundance of beetles and large beetles, although a significant interaction existed between trap type and site. Capture abundance of carabid beetles, ants and large ants was not significantly affected by the guide-arm trap. Spider capture abundance was significantly higher in the standard traps than in the guide-arm traps.

Introduction

Pitfall traps are one of the most commonly used techniques for sampling ground-dwelling invertebrates (Greenslade 1964). Attempts at standardising methodologies for biodiversity sampling have been documented (Toda and Kitching 2002); however, the protocols used will vary depending on the aims of the study (Hansen and New 2005). Variations in pitfall trap design include the type of preservative (Weeks and McIntyre 1997), trap size and type (Brennan *et al.* 2005, Borgelt and New 2005, Luff 1975), spatial arrangement (Perner and Schueler 2004, Ward *et al.* 2001), length of trapping period (Baars 1979) and site trap placement (Winer *et al.* 2001, Werner and Raffa 2000). The abundance and composition of the invertebrate catch will also be influenced by vegetation cover (Topping and Sunderland 1992, Melbourne 1999), seasonality (French *et al.* 2001) and duration and frequency of trapping. One of the trap design factors that influences the efficacy of the invertebrate catches is the use of drift fences or barriers. Many studies have been conducted using variations of these trap types (Durkis and Reeves 1982). The development of standardised sampling protocols, as suggested for ants by Agosti and Alonso (2000), which incorporate trap designs, facilitates comparisons between biodiversity studies.

In this study, the performance of a standard pitfall trap design (Bashford *et al.* 2001) was compared with that of a modified design utilising aluminium guide arms to attempt to increase the abundance of invertebrates caught. Guiding arms, previously referred to as 'guide vanes' (Durkis and Reeves 1982) or 'drift fences' (Brennan *et al.* 2005), help guide invertebrates into the pitfall cup. The mean catch abundance for the two trap types was examined for three arthropod taxa (beetles, ants and spiders), which are commonly used as target groups in biodiversity surveys. This was done to determine if different taxa respond differently to the guide arms. Within the beetle and ant groups, the proportion of larger morphospecies was compared between the two trap types to examine if the guide arm was biased towards catching larger invertebrates. Carabid abundance and composition were also looked at to determine any difference between catches of the two trap designs. Trap performance was studied under two different conditions: two levels of shading (shaded and unshaded) and two different vegetation types (pine and eucalypt plantations).

A standardised trap of improved design that is easily transported and assembled is required for the large number of biodiversity projects being conducted in native and commercial forest areas in Australia. The design presented in this paper enables a pack of ten traps to be easily transported by one person and assembled in the field.

Methods

Three factors were incorporated into the trial design:

Site

Pitfall traps were established at two different sites: a fifteen year old *Pinus radiata* plantation at Pittwater (147.5 E, -42.8 S) in southern Tasmania and an eight year old *Eucalyptus nitens* plantation at Blackwood Creek (147.98 E, -41.05 S) in northern Tasmania.

Vegetation cover

Within each site two areas were selected in which to place the traps. One area was open with very little canopy closure, which we refer to as unshaded. The other area had a closed canopy, which we refer to as shaded.

Trap type

Guide arm design

The guiding arm trap used in this study is a modification of a pitfall trap design used extensively for biodiversity studies by Forestry Tasmania (Grove 2009). The trap consists of a directing arm bracket that is made from a circular metal collar onto which four 10 mm diameter aluminium rods are welded. The outer diameter of the aluminium collar is 100 mm. This guiding arm bracket is attached to the standard pit trap tube (PVC pipe 90 mm diameter x 150 mm long) with adhesive-backed 2 mm thick foam tape. The bracket is then fixed to the trap tube using silicone sealant. Each of the four guiding arms per trap is made from flat 3 mm thick aluminium. The arms are 450 mm in length and 40 mm wide, each with a 10 mm diameter eye at one end. The plastic pitfall cup is a 90 mm diameter, 425 ml capacity, 'Castaway 2100' brand. A rain cover, consisting of a round plastic food container lid, 120 mm in diameter, supported by three 120 mm long bamboo skewers, is placed 10 mm above the lip of the cup (Fig. 1). Rain covers prevent dilution of the preservative fluid and have little impact on invertebrates entering the trap (Work *et al.* 2002).

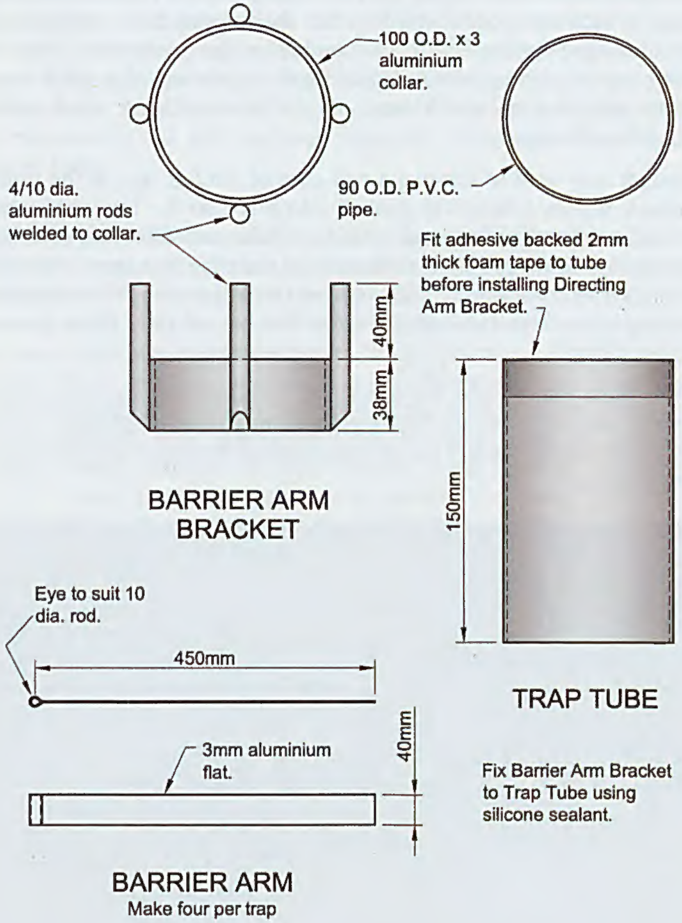

Fig. 1. Modified invertebrate pitfall trap with barrier arms.

Standard design

The standard pitfall trap consists of a PVC pipe (150 mm length, 90 mm diameter) inserted into the ground with the lip flush with the soil surface A plastic cup (425 ml capacity and 90 mm lip diameter) is placed inside the pipe and charged with 150 ml of preservative fluid. A rain lid similar to the modified design is fitted above the cup.

Trap establishment

All traps were established at the end of September 2007. At each site there were four treatments: shaded/guide arm, shaded/standard, unshaded/guide arm and unshaded/standard with two replicates per treatment. These eight traps were set up in four pairs with each pair consisting of a guide-arm trap and a standard pit trap which were set 1-2 metres apart. Each pair was established 5 metres apart.

A hand auger was used to remove a soil core of similar size to the trap tube. For standard pitfalls a tube was pushed into place so the top was level with the soil surface. For guiding arm pitfalls, a tube and directing arm bracket were placed into the cored hole so the top of the tube was level with the soil and the arm bracket sat on the soil surface. Once the tubes were in place the four guiding arms were placed onto the bracket so they were in a cross arrangement (Fig. 2).

The plastic cups placed into the tubes had a radius slightly larger than the tube so they sat level with the soil surface. Cups were filled with 150 ml of ethylene glycol mixed with 5 ml of non-scented detergent and covered with plastic rain covers.

Fig. 2. The components of the guide-arm trap include: the directing arm brackets attached to the metal collar and trap tube, collection cup, preservative (ethylene glycol) and rain cover.

Sample collection and processing
Traps were open for 6 months and serviced every 2 to 3 weeks until the end of March 2008. Over this period, Pittwater and Blackwood Creek had a total of 13 and 16 sets of samples respectively. Beetles, spiders and ants were removed from samples and counted. Within these groups, counts were made of beetles more than 8 mm in length, carabid beetles and larger ants of the genus *Myrmecia* (bull ants and jack jumpers). Only carabids were identified to species level.

Data analysis
As the main aim of the research was to compare the performance of the two pitfall trap designs, the factor of trap type was the focus of interest with consideration of the interactions present with the other two factors. The mean was taken of all samples for each trap. These means, for each invertebrate group, were then put into the program Statgraphics to carry out a three-way ANOVA. This analysis allowed us to determine the significance of differences between levels of the three main factors of site, trap type and level of shading, plus the interactions between each of six dependant variables, mean numbers of total beetles, large beetles, carabids, mean numbers of ants, larger ant species and spiders. The mean was taken of the two replicates per treatment and presented in bar graphs with standard error bars. Using the means per treatment, the ratio of specimens was calculated between the guide-arm and standard traps for the shaded and unshaded areas of each site. This was done to see if the ratio of specimen numbers was similar between beetles and large beetles and ants and large ants.

Results

All beetles
The mean beetle abundances were greater in the guide-arm traps than standard traps under all conditions (Fig. 3). The mean number of beetles caught per trap with guide-arm traps (27.49 ± 5.86 SE) was significantly higher than for standard traps (12.41 ± 5.86 SE) (Table 1); however, there was a significant interaction between site and trap type, suggesting that the effect of the guide arm is contingent on the sampled site (Table 1).

Overall catch abundance for all beetles was 3129 for Pittwater and 1101 for Blackwood Creek. The mean number of beetles caught per trap at Pittwater (31.3 ± 5.86 SE) was significantly higher than at Blackwood Creek (8.6 ± 5.86 SE) (Table 1). Guide-arm traps caught 2.01-4.35 times more total beetles at Pittwater than standard traps and 1.41-1.85 times more beetles at Blackwood Creek (Table 2), indicating that the guide-arm trap design was more efficient at the Pittwater site and demonstrating how the effect of the guide-arm is contingent on site.

Although the mean number of beetles caught per trap was significantly higher in shaded areas (26.29 + 5.86 SE) than in unshaded areas (12.41 + 5.86 SE), there was no significant second order interaction between trap type and shade, suggesting that the effect of the guide arm is not contingent on shade.

Table 1. Summary table of the three-way ANOVA, showing significance of differences between levels of the three main factors and their interactions for six dependent variables. All factors that have P-values less than 0.05 have a statistically significant effect on the dependant variables.

	Main factors			Interaction effects			
	Site (a)	Trap (b)	Shade (c)	a x b	a x c	b x c	a x b x c
Beetles	**<0.001**	**0.003**	**0.007**	**0.016**	**0.002**	0.72	0.4121
Large beetles	**<0.001**	**<0.001**	**0.038**	**0.002**	**0.014**	0.219	0.8819
Carabids	0.179	0.971	**0.018**	0.78	**0.018**	0.484	0.5821
Ants	**0.017**	0.643	0.083	0.168	0.673	0.471	0.8472
Large ants	**<0.001**	0.376	**0.019**	0.49	**0.021**	0.771	0.7292
Spiders	**<0.001**	**0.006**	**0.006**	**0.004**	0.921	0.261	0.9883

Large beetles

Results for large beetles (>8 mm) were generally similar to those for all beetles. The mean large beetle abundance was greater in the guide-arm traps than the standard traps under all conditions (Fig. 4). The mean number of large beetles caught per trap with guide-arm traps (4.40 ± 0.63 SE) was significantly higher than for standard traps (1.65 ± 0.63 SE); however, there was a significant interaction between site and trap type, suggesting that the effect of the guide arm is contingent on the sampled site (Table 1).

The overall catch abundance of large beetles was 422 at Pittwater and 235 at Blackwood Creek. The mean number of large beetles caught per trap at Pittwater (4.21 ± 0.63 SE) was significantly higher than at Blackwood Creek (1.84 ± 0.63 SE) (Table 1). The interaction between trap and site suggests that the guide-arm trap was effective only within the Pittwater site. Guide-arm traps caught 2.81-4.2 times more large beetles at Pittwater than standard traps and 1.36-2.55 times more large beetles at Blackwood Creek (Table 2). This indicates that the guide-arm trap design was more efficient at the Pittwater site and demonstrates how the effect of the guide-arm is contingent on site.

There was no significant second order interaction of mean large beetles caught between trap type and shade.

Traps with guide arms, under each condition, increased the mean beetle catch by 1.41-4.35 times and the mean large beetle catch by 1.36-4.2 times (Table 2). From these results it can be concluded that the guide-arm traps did not influence the proportion of large beetles caught but generally increased the total numbers in those traps.

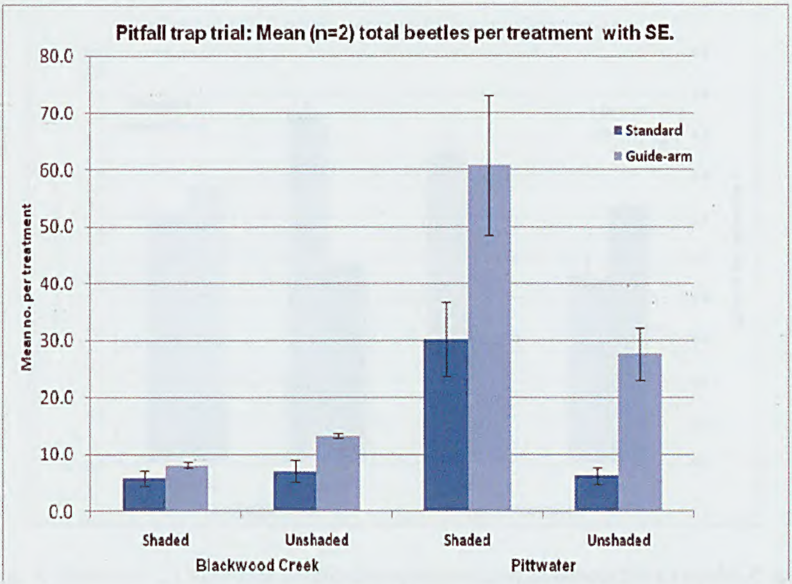

Fig. 3. Mean (n = 2) total beetles per treatment with SE.

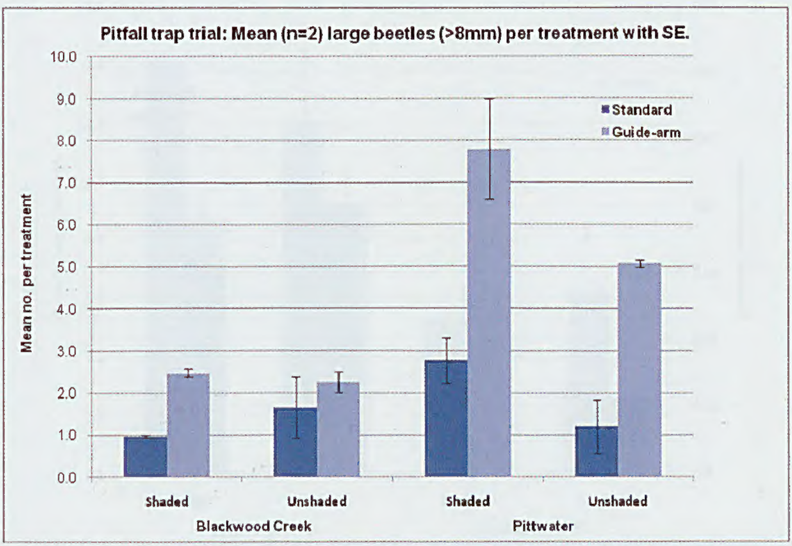

Fig. 4. Mean (n = 2) large beetles (>8 mm) per treatment with SE.

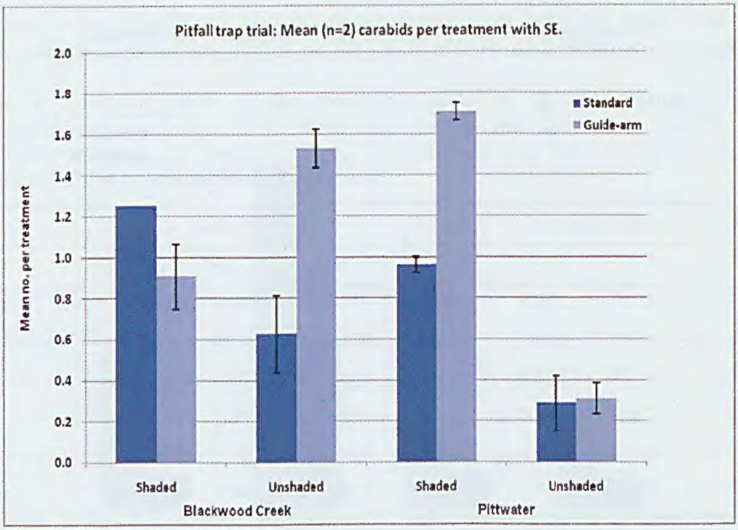

Fig. 5. Mean (n = 2) carabids per treatment with SE.

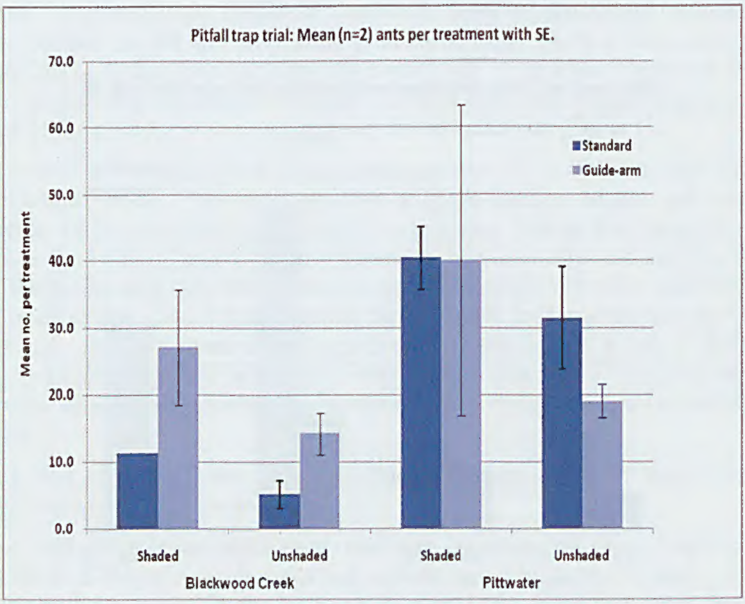

Fig. 6. Mean (n = 2) ants per treatment with SE

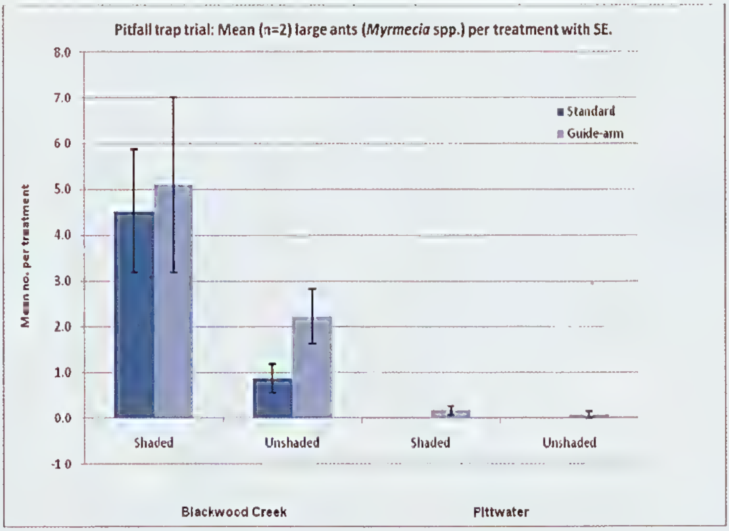

Fig. 7. Mean (n = 2) large ants (*Myrmecia* spp.) per treatment with SE.

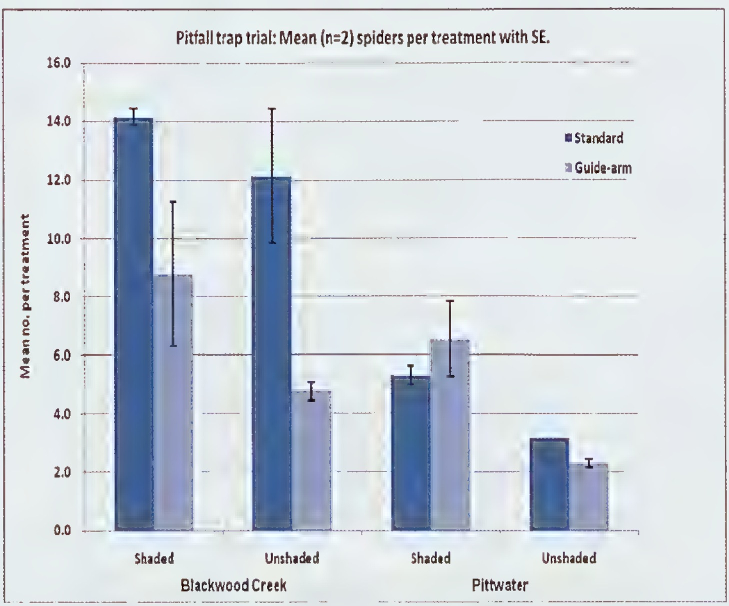

Fig. 8. Mean (n = 2) spiders per treatment with SE.

Table 2. Means of the two reps per treatment and the proportion of catch by the two trap types. BC = Blackwood Creek; PW = Pittwater; SH = Shaded; UN = Unshaded; GA = Guide Arm; ST = Standard.

Treatment	Beetles	Ratio	Large Beetles	Ratio	Carabids	Ratio
BC SH GA	8.22	**1.41**	2.47	**2.55**	0.91	**1.00**
BC SH ST	5.84	**1.00**	0.97	**1.00**	1.25	**1.37**
BC UN GA	13.22	**1.85**	2.25	**1.36**	1.53	**2.43**
BC UN ST	7.13	**1.00**	1.66	**1.00**	0.63	**1.00**
PW SH GA	60.79	**2.01**	7.79	**2.81**	1.71	**1.78**
PW SH ST	30.31	**1.00**	2.77	**1.00**	0.96	**1.00**
PW UN GA	27.73	**4.35**	5.08	**4.20**	0.31	**1.07**
PW UN ST	6.38	**1.00**	1.21	**1.00**	0.29	**1.00**

Treatment	Ants	Ratio	Large Ants	Ratio	Spiders	Ratio
BC SH GA	27.13	**2.41**	5.09	**1.12**	8.78	**1.00**
BC SH ST	11.25	**1.00**	4.53	**1.00**	14.16	**1.61**
BC UN GA	14.19	**2.77**	2.22	**2.52**	4.75	**1.00**
BC UN ST	5.13	**1.00**	0.88	**1.00**	12.16	**2.56**
PW SH GA	40.13	**1.00**	0.17		6.54	**1.23**
PW SH ST	40.50	**1.01**	0.00		5.31	**1.00**
PW UN GA	19.04	**1.00**	0.08		2.31	**1.00**
PW UN ST	31.53	**1.66**	0.00		3.16	**1.37**

Carabids

Mean carabid abundance was greater in the guide-arm traps under three of the conditions (Fig. 5); however, no significant difference existed between levels for the main factor of trap type (Table 1). The overall catch abundance of carabids was 81 for Pittwater and 138 for Blackwood Creek. Ten species were captured, of which three (*Harpharpax peronii* (Castelnau), *Homethes elegans* Newman and *Simodontus australis* (Dejean)) were common to both sites. *H. peronii* was the most common species at both sites (Pittwater 43 specimens and Blackwood Creek 39 specimens). Fewer than 10 specimens of all other species were collected, with 3 species being singletons. There was no significant difference between the number of species collected in guide-arm (9 species) or standard traps (8 species) and no significant interaction existed between site and trap type (Table 1).

Although there was a significantly higher mean number of carabids caught per trap in shaded areas (1.21 ± 0.29 SE) than in unshaded areas (0.69 ± 0.29 SE), there was no significant interaction between shade and trap type.

Ants

Mean ant abundance was greater in the guide-arm traps at Blackwood Creek but not at Pittwater (Fig. 6). No significant difference existed between levels for the main factor of trap type (Table 1). The overall catch abundance of total ants for Pittwater was 3307 and for Blackwood Creek was 1846. The mean number of ants caught per trap at Pittwater (32.8 ± 10.08 SE) was significantly higher than at Blackwood Creek (14.42 ± 10.08 SE); however, there was no significant second order interaction of mean ants caught between trap type and site (Table 1). There was no significant second order interaction between trap type and shade.

Large ants

Mean large ant abundance was greater in the guide-arm traps under all conditions (Fig. 7); however, no significant difference existed between levels for the main factor of trap type. The overall number of large ants caught was 6 at Pittwater and 407 at Blackwood Creek. The mean number of large ants caught per trap at Blackwood Creek (3.18 ± 0.92 SE) was significantly higher than for Pittwater (0.06 ± 0.92 SE) (Table 1); however, there was no significant interaction between trap type and site. Although there was a significantly higher mean number of large ants caught per trap in shaded areas (2.44 ± 0.92 SE) than in unshaded areas (0.79 ± 0.92 SE), there was no significant second order interaction between trap type and shade. Traps with guide arms at Blackwood Creek, under both shaded and unshaded conditions, increased the mean ant catch by 2.41-2.77 times and the mean large ant catch by 1.12-2.52 times (Table 2). This indicates that the proportion of large ants to overall ant catch remained the same between the two trap types.

Spiders

Mean spider abundance was greater in the guide-arm traps for only one condition (Fig. 8). A significant difference existed between levels for the main factor of trap type but the mean abundance was higher for the standard traps (8.70 ± 1.37 SE), rather than for the guide-arm traps (5.6 ± 1.37 SE). The overall abundance of spiders caught at Pittwater was 434 and at Blackwood Creek was 1275. The mean number of spiders caught per trap at Blackwood Creek (9.96 ± 1.37 SE) was significantly higher than Pittwater (4.33 ± 1.37 SE); however, there was a significant interaction between site and trap type, suggesting that the effect of the standard trap is contingent on the sampled site (Table 1).

Although there was a significantly higher mean number of spiders caught per trap in shaded (8.7 ± 1.37 SE) than in unshaded areas (5.59 ± 1.37 SE), there was no significant second order interaction between trap type and shade.

Discussion

The prime purpose of this study was to compare traps, with and without guide arms, to determine which was most effective in capturing specific taxa. Traps were tested in two different habitats and two shade levels to determine if performance was consistent in a range of situations. It would be expected that in two different habitats, such as eucalypt and pine plantations, the species composition and abundance would vary due to habitat differences. A variable such as shade controls light intensity and reduces direct rainfall and shadow movement, which would influence the behaviour patterns of different species.

While mean catches of all groups except spiders were higher for the guide-arm trap than the standard trap, this was only significant for beetles and large beetles. The mean number of spiders captured was statistically higher for the standard trap compared with the guide-arm trap.

The interactions found between trap and site for beetles and large beetles indicate that when using this trap design it must be kept in mind that the efficacy is dependent on site or shade levels. From the results it can also be concluded that the guide-arm traps did not influence the proportion of large beetles caught but generally increased the total numbers in those traps.

Significantly higher mean numbers of beetles, large beetles and ants were present in the pine site at Pittwater, which may reflect a habitat preference for these groups. This result contrasts with significantly higher means for large ants and spiders present in the eucalypt site at Blackwood Creek. The mean number of carabids at Blackwood Creek was not significantly higher than at Pittwater. The significant interaction between trap and site for spiders suggests that the standard trap was more effective than the guide-arm trap.

Although the guide-arm trap was not more effective at trapping ants or larger ants across different conditions, it is interesting to note that even though mean abundance of ants was greater at Pittwater, mean abundance of large ants was greater at Blackwood Creek. This could be because the larger *Myrmecia* species tend to nest in open, sunny sites or under a diffuse eucalypt canopy rather than the denser pine canopy. Results indicate that at Blackwood Creek the proportion of catches between the two trap types remained the same for large ants and total ants. Guide-arms are therefore not favouring the capture of large ants.

The difference in capture effectiveness between certain arthropod groups may be influenced by the mobility of the invertebrates. Ground-dwelling beetles are generally less mobile and move at a slower rate than ants or spiders; therefore when they come into contact with the guide arm they would then be guided in one direction or the other. However, when ants and spiders come in contact with the guide arm their mobility may allow them to be guided in either direction or to reverse their direction.

Ground-dwelling beetles such as carabids are frequently used as indicator species for biodiversity studies. This study demonstrates that when sampling for beetles, including carabids, the guide arm design is effective at capturing more individuals but not necessarily more species. Luff (1975) showed that standard pitfall traps of a range of sizes captured about 75% of the carabids that contacted the perimeter of the trap. By increasing the number of beetles likely to contact the edge of the trap by 'guiding' them towards the trap, we can increase trap efficiency. Similar results of trap catch increase, by at least an order of magnitude, were recorded by Winder *et al.* (2003) using barrier arrays, particularly for some invertebrate groups such as carabid and staphylinid beetles and lycosid spiders. Although mean catches were significantly higher in shaded trap sites for all groups except ants (Table 1), there was no significant interaction between trap type and shade.

Practical constraints on the transport and storage of the traps limited guide arm length in this study, which was arbitrarily selected as the length (450 mm) that fitted into the storage containers selected to hold ten complete guide-arm trap kits. We also found that having a rigid guide arm that fitted flush with the litter/soil surface gave more consistent results in terms of reduced trap disturbance than 'dug-in' flexible aluminium barriers. Hansen and New (2005) found that traps with guide arms arranged in a simple cross increased overall beetle catch, including carabids, by 3-8.7 times and the number of morphospecies by 1.3-2.1 fold. Durkis and Reeves (1982) used traps with a single pair of guide arms, at 180 degrees to each other, with the collecting vial in the centre. This design proved useful as their study was examining the directional movement of organisms between two habitat types. Generally, increasing the length of guide arms progressively increases the invertebrate catch (Hansen and New 2005).

Biodiversity studies within forests are often opportunistic, especially in remote areas, occur at times of pest and disease incidence, or are part of distribution studies. While many environmental factors, such as seasonality or habitat type, cannot be controlled from one survey to the next, the use of standard collection methodology allows some comparisons between surveys. The guide-arm trap used in this study provides a cheap, easily transported and assembled pitfall trap that can be used to obtain species records of ground-dwelling taxa, especially in remote sites or those with difficult access.

Acknowledgements

We thank Forestry Tasmania personnel Steve Smedley for preparing the technical drawing and Byron Garrod for manufacturing the pitfall trap units.

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